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100 Percent Renewable Generation in Costa Rica – A Possibility?

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Introduction

Costa Rica is a Central American country, with a population of around 4.5 million people. Questions may arise on why the energy system of such a small country is of interest. There are several aspects which are unique for Costa Rica – In the last few years the country covered 98.2 % of its electricity demand only by electricity generation from renewable sources. Another achievement is that they ran the country for 110 days straight without burning any fossil fuels. There are of course several differences when compared to the energy sector of a country like Austria, but how the energy system developed this way, how it functions today, and how they plan to maintain a secure supply of electricity in the future are some points which are of interest. Some interesting research questions arise, like whether there is still renewable potential to be sustainably exploited, is a 100 % renewable energy system possible, and whether the country becomes the world's first CO_2-free country as they intend to. The electricity sector of Costa Rica has an interesting mix of generation technologies at play. The electrical generation and the mix of the installed capacity in Costa Rica are as shown in (Fig. 1). Hydropower has the biggest share both in installed capacity and generation. For Geothermal energy the generated energy share is twice the share of the installed capacity. This is due to the fact that the plants run 24 hours a day as baseload power plants. The biggest difference is for thermal power, the generated electricity is only 1,8 %, while the installed capacity makes up 16,5 %. This capacity is necessary to compensate the reduced availability of hydropower during the dry season.

Hydro power is the main source used for electricity generation, in 2016 it made up 74.4 % of the total generation. The thermal power plants are mainly used in combination with energy imports, to compensate for missing capacity in the dry season. The country is a pioneer for wind energy in Latin America. The first turbines were installed in 1996, and in 2016 about 10 % of the electricity demand was covered by wind power. In the last decade, the installed capacity has multiplied by a factor of five (66 MW in 2006, 319 MW in 2016). Costa Rica has active volcanoes and thus also uses geothermal energy for the generation of electricity. In 2016, 12.4 % of the electricity was generated only by geothermal power plants. The country also has plans to expand their geothermal capacity (5).

Analysis: 100 % Hybrid System. A possibility?

In the rainy season, the monthly average rainfall is between 300 mm and 400 mm. During the dry season it varies between 80 mm and 120 mm. Combined with the fact that the country produces 74,4 % from hydroelectric sources, this becomes a challenge for the energy supply i.e., hydro power plants generate lesser electricity. In February and March, which are some of the driest months in the dry season, thermal power plants compensate the biggest lack of production of these large hydro power plants. The reservoirs are mostly empty at this time and there is only little rain. To eliminate or at least reduce this dependence on the thermal power plants, a hybrid system of renewable sources is proposed as an alternative in this paper.

Wind-Solar-Geothermal-Hydro Hybrid System

One way to compensate the lack of water without burning fossil fuels would be to raise the capacity of wind power. In Costa Rica, wind energy is a good complement to hydroelectric power throughout the year and especially in the dry season (Fig. 1). The best wind conditions are obtained in the dry season when the flow of rivers decrease. Additionally, the El Niño phenomenon cycles (dry years) provide more windy conditions, favouring a greater generation with wind energy. In the La Niña cycles (very rainy years) there is less wind, but there is more hydroelectric generation. The identified potential for wind power is about 2400 MW. Solar power is also a relatively stable during the dry season. To compensate the evening peak, the big storage hydro power plants would have to run in this period of the day. Geothermal energy generation is quite stable and can be still used for base load generation.

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Visualization of the Transmission Network using ATLANTIS

A model for Costa Rica was developed to visualize the power grid and the power plants in Costa Rica, using the techno economic model ATLANTIS (Fig. 2). Subsequently, a complete model-based analysis approach is in the works, to analyze the country's energy strategies and the electricity economics.

Conclusion

The goal to become 100 % fossil fuel free is rather utopic, during the dry season the thermal capacity is needed to compensate the lack of water. With a hybrid system this is still the case, but the dependence can be significantly reduced. The strong months from October to December where the availability of hydro resources is high, can be used to fill up the big reservoirs. Pump storage should be put into operation in the big reservoir power plants, this can be used to balance the wind power more efficiently and reduce the need for imports or thermal power plants during the peak demand of the day. The SPIEPAC line can reduce the dependence on thermal power plants as well, the import from neighbour countries can be used to stabilize the energy system.

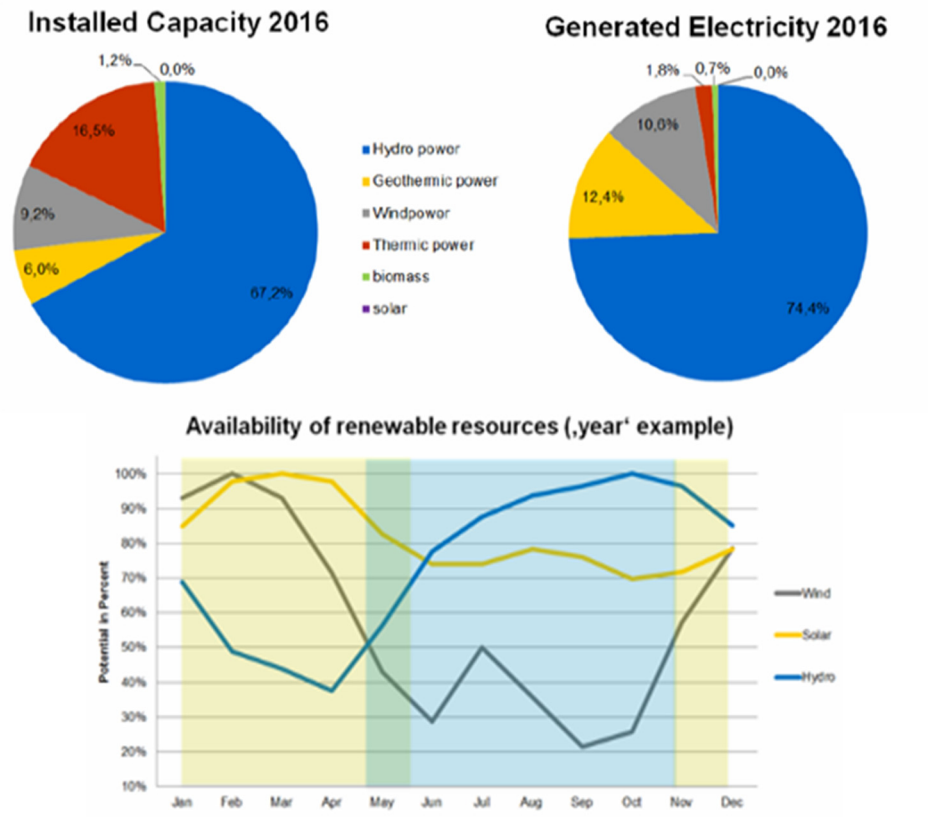

Figure 1: Installed power plant capacity and the electricity generated in Costa Rica, 2016 (1) and Seasonal availability of renewable energy resources in Costa Rica: Wind, Sola, Hydro [10]

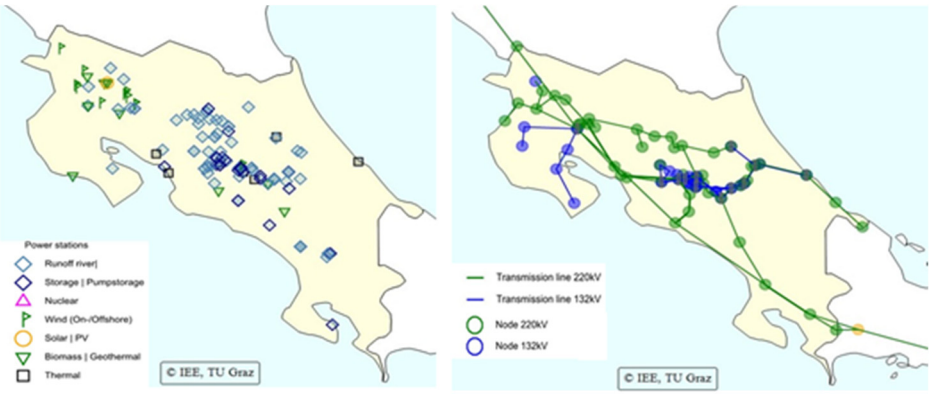

Figure 2: A visualization of the grid and power plants

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